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The production of symbolic and non-symbolic numerals

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Abstract

Symbolic and non-symbolic numerals activate semantic information in number comprehension. This study explored whether semantic processing of numerals in production is also produced irrespective of number format. We indexed semantic access with the interference effect observed in the blocking paradigm (Kroll & Stewart, 1994). Symbolic and non-symbolic numerals were named in a mixed context (numerals and other semantic categories were intermixed) and a blocked context (numerals were grouped by category). Semantic interference was found for non-symbolic numerals but not for symbolic numerals. We concluded that number production does not imply semantic mediation necessarily and that number format makes the difference.

Keywords: Numbers production, semantic blocking.

1. Introduction

A debated question in numerical cognition regards to the processing stages required to name a number target as a function of its notation. Authors agree that number words similar to other words do not require access to conceptual codes (e.g., Dehaene, 1992; Fias, Reynvoet, & Brysbaert, 2001; McCloskey, 1992). The orthographic representation of a word specifies its pronunciation because letter symbols systematically map onto phonemes (e.g., Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). However, for Arabic digits there are two opposing views. On the one hand, the hypothesis of a semantic route suggests that semantic mediation is required for producing this type of symbols (e.g., Brysbaert, 1995; Damian, 2004; Fias, 2001; Fias et al., 2001). On the other hand, the hypothesis of an asemantic route proposes that the naming of Arabic digits takes place similar to word naming (e.g., Cipolotti & Butterworth, 1995; Dehaene, 1992). This debated question, therefore, could be summarized as follows: Are Arabic digits named like pictures or like words?

Arabic digits differ from words because the form of a digit is only arbitrarily related to its corresponding phonological form. But they also differ from pictures since digits have an arbitrary relation with the concept they express.

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Several authors have argued in favour of the semantic route taking evidence that shows a faster and more automatic access to the semantic representation from digits than from number words (e.g., Damian, 2004; Fias, 2001; Fias, Brysbaert, Geypens, & D'Ydewalle, 1996; Ito & Hatta, 2003). However, the main body of research in this issue has made use of the priming paradigm when participants perform a naming task. A first study in this vein was made by Brysbaert (1995) who reported that naming a digit preceded by a closer number produced faster responses. He also found that responses to numbers follow a logarithmic magnitude effect. He interpreted these two effects as the result of an obligatory access to the semantic representation of Arabic digits. The effects produced in naming tasks with a priming paradigm have been subsequently explored with consistent results. For both digit naming and number word naming, similar facilitative effects are found from digit and number word primes (e.g., Ischebeck, 2003; Reynvoet & Brysbaert, 2004; Reynvoet, Brysbaert, & Fias, 2002; Roelofs, 2006). However, there are several interpretations of these effects. For example, Reynvoet et al. consider that for naming digits and words, two routes are simultaneously activated (i.e., semantic mediation and non-semantic conversion), although the relative speed of each route differs as a function of notation, being the semantic route faster for digits and the non-semantic route faster for number words. In experimental conditions where the semantic route is pre-activated, the semantic system can influence the naming of verbal numerals. In a different position, Roelofs has argued that these effects resemble those previously found in psycholinguistic research on word naming with word primes, and they differ from the results found in picture naming with word primes. Moreover, he showed that interference instead of a facilitative effect was found when participants were asked to name pattern of dots (i.e., physical numerosity) with digits or number words as primes. He concluded that both Arabic digits and number words may be named through an asemantic route.

In a recent work (Herrera & Macizo, in press), we proposed an alternative strategy to analyse this issue by adapting the semantic blocking paradigm which has been previously considered to examine the semantic access in picture naming and word naming (Kroll & Curley, 1988). In Experiment 1, participants were asked to name exemplars from several semantic categories while numbers were introduced as another category. The exemplars were pictures and Arabic digits or they were words and number words. The context in which the items appeared was manipulated so they were grouped by category (blocked context) or they were intermixed with items from different semantic categories (mixed context). The results showed that for the non-numerical categories the blocked context produced longer response latencies relative to the mixed context when the items to be named were pictures but not when they were words. This pattern replicated previous studies with this paradigm (e.g., Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994). This differential effect of semantic context between word and picture naming is generally interpreted as a consequence of the different processing stages required for accessing to the word-form from words and pictures. Picture naming requires the accessing to a conceptual level in which activation spreads to semantically related concepts and then, to the lemma level. It is at this level were interference takes place as a function of the co-activated lexical entries. However, printed words do not require a previous step to the conceptual level; they directly activate the word-form and, therefore, there is no place for semantic interference (e.g., Damian et al., 2001; Glaser, 1992; Kroll & Stewart, 1994; Levelt, 1992). More important for the present study was the result obtained in the numerical category. The blocked semantic context did not produce interference but facilitation relative to the mixed context with both number words and Arabic digits. Therefore, following the arguments in the blocking paradigm literature, the absence of interference in the blocked context indicated that naming digits did not require a first step of accessing to semantic representation but a direct access to lexical entries took place.

In the present study we followed this line of research and addressed some additional questions by using the semantic blocking paradigm with numerical stimuli. In Experiment 1, we explored whether the facilitative effects of the semantic blocked condition for Arabic digits and number words were modulated by the way in which other stimuli were presented in the task. In Experiment 2, we evaluated whether physical numerosities (i.e., pattern of dots) need semantic mediation or they can be named bypassing semantic as number words.

2. Experiment 1

One suggestion derived from previous studies is that response latencies depend on the criteria that participants adopt in deciding when to respond (e.g., Lupker, Brown, & Colombo, 1997; Meyer, Roelofs, & Levelt, 2003; Taylor & Lupker, 2001). This criterion is not fixed for the entire experimental task, but during the experiment, the criterion can be continuously updated depending on the difficulty of the stimuli already encountered (e.g., Meyer et al.,

2003). This suggestion might explain the facilitative effect observed when Arabic digits are named in a blocked context (Herrera & Macizo, in press). In the Herrera and Macizo's study, all stimuli in the blocked condition were digits so participants adopted an optimal criterion to respond. However, in the mixed condition digits were intermixed with pictures which are usually responded to more slowly than words. In this situation, the participants might increase the criterion to respond due to the influence of the responses to pictures in the mixed condition. Therefore, the faster responses in the blocked context relative to the mixed context could be due to differences in the response criterion between these two conditions.

This experiment was aimed to explore whether the facilitative effects of the blocked context in the Herrera and Macizo's (in press) study depended on the stimuli that accompanied Arabic digits in the mixed condition (i.e., pictures). To this end, we changed the type of stimuli that accompanied the numerical categories in Experiment 1: Arabic numbers were presented with words, and number words were presented with pictures. If the facilitative effect observed with the numerical categories in the Herrera and Macizo's study did not depend on the rest of stimuli presented in the task, the same facilitative effect of the blocked context might be observed in this experiment.

2.1. Method

2.1.1. Participants

Forty students (30 females) at the University of Murcia participated for course credits. All were native Spanish speaker. The range of age was between 18 and 30 years old (M = 21 years). All had normal or corrected-to-normal visual acuity.

2.1.2. Stimulus Materials and Apparatus

Twenty-five common objects were selected from five semantic categories (vehicle, furniture, animal, body-part, and number). The stimuli were arranged in a matrix of 5 x 5 items (see Damian et al., 2001). The rows corresponded to categories and formed the blocked category stimulus sets. The columns formed the mixed stimulus sets. We created 10 lists of stimuli. We used the items in the rows for five of the lists (blocked category lists), and the items in the columns for the other five lists (mixed category lists). The five items were repeated five times in a pseudorandom order within each list so that each item was sampled once before any item was repeated in the list and the same item never appeared twice in succession. For the picture naming condition the stimuli were line drawings of the objects and number words (corresponding to 1, 4, 7, 8 and 9). The object pictures were taken from Pérez and Navalón (2003) and from Snodgrass and Vanderwart (1980). For the word naming condition the stimuli were the most common names of the objects in Spanish (Pérez & Navalón, 2003) and Arabic digits. The average size of the pictures and Arabic digits was 7 cm high and 7 cm wide. The words were presented in capital letter Courier New font and they were on average 1.5 cm high and 3 cm wide. The experiment was controlled by a Genuine-Intel compatible PC 1.73 GHz, using E-prime experimental software, 1.1 versions (Schneider, Eschman, & Zuccolotto, 2002). Instructions and stimuli were presented on a 17" screen located at approximately 60 cm in front of the participant. Response latencies were collected using a PST Serial Response Box (Psychology Software Tools) and tape-recoded to eliminate trials with errors in the latency analyses.

2.1.3. Design and Procedure

The type of task (picture naming or word naming) was manipulated as a between-subject variable. Half of the participants were randomly assigned to the number word/picture naming condition and half to the digit/word naming condition. The semantic context (mixed vs. blocked) was manipulated as a within-subject variable. All the participants performed four experimental blocks (two blocked and two mixed) that were presented in ABBA design. Half of participants in each type of task condition started with the blocked category and the other half with the mixed category. Within each blocked category block, the five blocked category lists (see above) were randomly presented. Within each mixed block, the five mixed category lists were randomly presented. Each block consisted of 125 trials; therefore, there were a total of 500 experimental trials. On each trial, a fixation cross was presented for 500 ms. After a blank period of 500 ms, the stimulus to be named was shown for 500 ms. Latencies were measured from the onset of the stimulus until the subject's response or until 1000 ms. The next trial started after 1000 ms. There were short breaks between lists and between blocks.

Before the experimental trials, the participants were presented with a set of cards. Each card contained one of the pictures with its more common name in Spanish or one of the words. Participants were told to examine the pictures and the words because they would have to name them later on. All the participants performed four practice trials.

2.2. Results and Discussion

Trials on which an incorrect response was provided or the equipment had malfunctioned were excluded (1.56%). A cut-off point of 3 *SD* was used to exclude outliers (3.05%) from the reaction time (RT) analyses. Table 1 gives mean latencies and standard errors for each category in the different experimental conditions of Experiment 1.

Table 1. Mean RTs (in milliseconds) and standard errors (in parenthesis) as a function of Type of task (Number word/Picture naming and Digit/Word naming), Type of context (Mixed and Blocked) and Category (vehicle, furniture, animal, body-part and number) obtained in Experiment 1. Last row for each type of task shows the difference in RTs between Blocked and Mixed context.

	Number word/Picture naming				
	Vehicle	Furniture	Animal	Body-part	Number
Blocked context	561 (9)	543 (9)	558 (10)	540 (9)	417 (10)
Mixed context	545 (9)	513 (9)	541 (10)	519 (9)	451 (9)
Blocked-Mixed	16	31	17	20	-34
	Digit/Word naming				
Blocked context	403 (9)	397 (9)	420 (10)	407 (9)	395 (10)
Mixed context	413 (9)	394 (9)	412 (10)	402 (9)	427 (9)
Blocked-Mixed	-10	3	8	5	-32

Following previous studies (e.g., Damian et al., 2001; Kroll & Stewart, 1994), we grouped RTs of all categories except numbers. We conducted an overall analysis of variance (ANOVA) with Type of task (digit/word naming vs. number-word/picture naming) as a between-subjects factor and Category (number vs. others categories) and Semantic context (blocked vs. mixed) as within-subject factors. The results showed significant the main effects of type of task, $F(1, 38) = 40.57$, $MSE = 6181$, $p < .001$; category, $F(1, 38) = 313.14$, $MSE = 322$, $p < .001$; and context, $F(1, 38) = 21.53$, $MSE = 1241$, $p < .001$. Those effects were modulated by the other factors as indicated by the significant Type of task x Category interaction, $F(1, 38) = 388.22$, $MSE = 322$, $p < .001$; Type of task x Semantic context interaction, $F(1, 38) = 5.84$, $MSE = 212$, $p < .05$; and Category x Semantic context interaction, $F(1, 38) = 154.05$, $MSE = 127$, $p < .001$. Moreover, the second order Type of task x Category x Semantic context interaction also was reliable, $F(1, 38) = 9.99$, $MSE = 127$, $p < .005$. Therefore, we proceeded with separate 2 (Type of task) x 2 (Semantic context) ANOVAs for non-numerical stimuli and numerical stimuli. For non-numerical stimuli, it showed significant the main effect of the type of task, $F(1, 38) = 118.65$, $MSE = 3078$, $p < .001$, and the main effect of the semantic context, $F(1, 38) = 40.68$, $MSE = 64$, $p < .001$. The Type of task x Semantic context interaction also was reliable, $F(1, 38) = 39.30$, $MSE = 64$, $p < .001$. The effect of the semantic context was significant for pictures, $t(19) = 7.66$, $p < .001$. The response latencies in the blocked context were longer (554 ms) than in the mixed context (531 ms). For word naming the context effect was not reliable ($t < 1$). Therefore, the semantic blocked context produced an interference effect in picture naming but not in word naming. For numerical stimuli, the analysis resulted in the significant main effect of the semantic context, $F(1, 38) = 78.04$, $MSE = 275$, $p < .001$. Responses in the blocked context were faster (408 ms) than in the mixed context (441 ms). Neither the type of stimuli nor the interaction was reliable ($p > .05$).

The results of the present experiment indicated that the facilitative effects of blocked context in naming non-numerical stimuli (Herrera & Macizo, in press) did not depend on the stimuli that accompanied Arabic digits and number words. Figure 1 summarizes the blocked effects for non-numerical and numerical categories. On the one hand, the interference effect produced by the blocked context relative to the mixed context in the non-numerical categories occurred for picture naming but not for word naming, which replicated previous studies (e.g., Damian et al., 2001; Kroll & Stewart, 1994). As we explained above, this pattern of results is an index of the difference

between the naming of pictures and words. Pictures require a conceptual mediation in order to reach the lexical level while words directly access to the lexical level. On the other hand, for the numerical category we found a facilitative effect of the blocked context relative to the mixed context, which was similar for both types of notation (i.e., Arabic digits and number words). In this case, the absence of interference of the blocked context took place even in a situation in which digits were among a type of stimuli that produce faster responses (see Table 1). Therefore, the present results indicate that the absence of interference in the blocked context relative to the mixed context does not depend on the modality in which other categories are presented during the naming task.

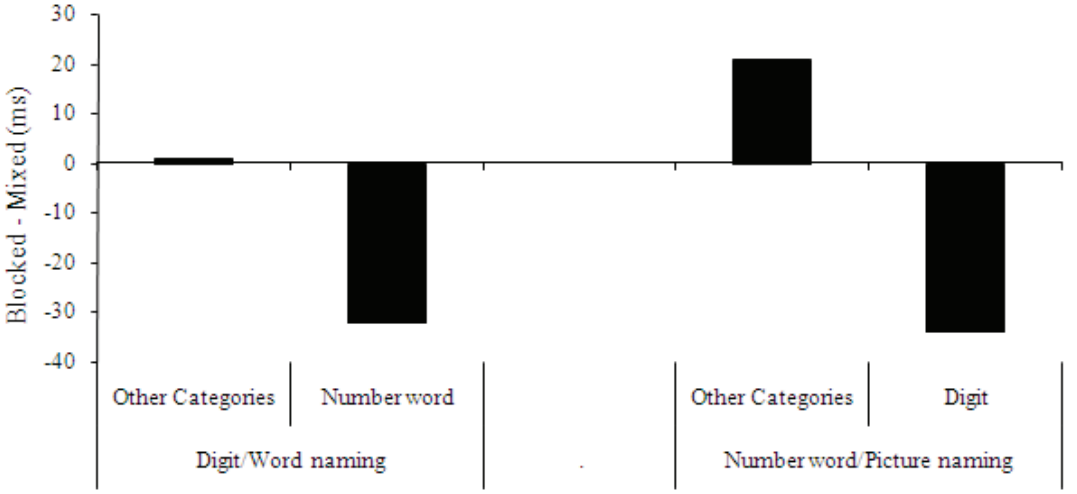

Figure 1. Effect of blocked context (Blocked – Mixed condition) for the different conditions used in Experiment 1.

Experiment 2

The results obtained in Experiment 1 suggested that numerical symbols (Arabic digits and number words) can be named bypassing semantic. In Experiment 2, we asked whether this is a general conclusion and hence, number naming never requires semantic processing. It might be possible that the not semantic processing of numerals only applies to the production of numerical symbols. The naming of physical numerosities seems to have much more in common with picture naming. Indeed, models of number cognition (e.g., Dehaene, 1992; McCloskey, 1992) assume that in order to say the numerosity of a set, an obligatory step is the accessing to the magnitude representation. In this experiment we explored whether semantic processing is required during the production of non-symbolic numerals (i.e., dice faces). This type of stimuli has been previously used in studies aimed to compare the accessing to magnitude representation from digits, words and physical numerosity (e.g., Herrera & Macizo, 2008; Roelofs, 2006; Temple & Posner, 1998). In Experiment 2, the participants were asked to name dice faces and pictures while the semantic context was manipulated. We compared this situation with another in which participants named digits and pictures. If semantic processing is required for the naming of physical numerosities, interference effects would be expected when participants name dice faces in a blocked context.

2.3. Method

2.3.1. Participants

Thirty-six students (31 females) at the University of Murcia participated for course credits. All were native Spanish speaker. The range of age was between 18 and 29 years old (M = 22 years). All had normal or corrected-to-normal visual acuity.

2.3.2. Stimulus Materials and Apparatus

The same stimuli and apparatus of Experiment 1 were used here. The only differences were that number words were replaced by canonical patterns of dots (dice) and that exemplars of non-numerical categories were always presented as pictures.

2.3.3. Design and Procedure

All the participants performed a picture naming task. However, the numerical category was presented as Arabic digits for half of the participants and as dice faces for the rest of participants. Therefore, the numerical notation (digit or dice) was manipulated as a between-subjects variable. The semantic context (mixed vs. blocked) was manipulated as a within-subject variable. In all the other aspects the design and procedure were equal to Experiment 1.

2.4. Results and Discussion

Trials on which an incorrect response was provided or the equipment had malfunctioned were excluded (3.97%). A cut-off point of 3 *SD* was used to exclude outliers (1.71%) from the RT analyses. Table 2 shows mean latencies and standard errors for each category in the different experimental conditions of Experiment 2.

Similar to the Experiment 1 we grouped RTs of all categories except numbers and we conducted an ANOVA with Type of task (Picture/Digit naming vs. Picture/Dice naming) as a between-subjects factor, and Category (numerical vs. others) and Semantic context (blocked vs. mixed) as within-subject factors. All the main effects were significant. The type of task effect, $F(1, 34) = 6.77$, $MSE = 16240$, $p < .05$, resulted from the longer response latencies in the picture/dice condition (545 ms) than in the picture/digit condition (490 ms). The category effect, $F(1, 34) = 67.77$, $MSE = 493$, $p < .001$, showed that the responses to numbers (502 ms) were faster than the responses to the other categories (533 ms). The semantic context effect, $F(1, 34) = 5.88$, $MSE = 378$, $p < .001$, showed that the responses in blocked condition (521 ms) were longer than in the mixed condition (513 ms). All the first order interactions were reliable, Type of task x Category, $F(1, 34) = 276.09$, $MSE = 493$, $p < .001$; Type of task x Semantic context, $F(1, 34) = 29.12$, $MSE = 378$, $p < .001$; and Category x Semantic context, $F(1, 34) = 22.75$, $MSE = 417$, $p < .001$. More important, the Type of task x Category x Semantic context interaction was significant, $F(1, 34) = 34.99$, $MSE = 417$, $p < .001$. In order to examine the second order interaction, we conducted separate 2 (Category) x 2 (Semantic context) ANOVAs for each type of task condition. The analyses on the RTs of the picture/digit condition resulted in the significant effect of the category, $F(1, 17) = 233.06$, $MSE = 653$, $p < .001$, and the semantic context, $F(1, 17) = 6.23$, $MSE = 268$, $p < .05$. The Category x Semantic context interaction was also significant, $F(1, 17) = 211.98$, $MSE = 112$, $p < .001$. The Semantic context was reliable for Arabic digits, $t(17) = 9.17$, $p < .001$, and for pictures, $t(17) = 6.48$, $p < .001$. However, as Figure 2 shows, the blocked context relative to the mixed context produced interference for Arabic digits while it produced facilitation for pictures. The analyses on the picture/dice condition showed that the effect of category was reliable, $F(1, 17) = 52.03$, $MSE = 333$, $p < .001$, and also was significant the effect of semantic context, $F(1, 17) = 23.69$, $MSE = 488$, $p < .001$. The category by semantic context interaction was not reliable ($F < 1$). In this condition, for both picture and dice the responses in the blocked context were slower than in the mixed context.

Table 2. Mean RTs (in milliseconds) and standard errors (in parenthesis) as a function of Type of task (Picture/Dice naming and Picture/Digit naming), Type of context (Mixed and Blocked) and Category (vehicle, furniture, animal, body-part and number) obtained in Experiment 2. Last row for each type of task shows the difference in RTs between Blocked and Mixed context.

	Picture/Dice naming				
	Vehicle	Furniture	Animal	Body-part	Number
Blocked context	541 (17)	539 (15)	556 (17)	524 (17)	575 (16)
Mixed context	529 (14)	512 (14)	524 (16)	510 (15)	546 (16)
Blocked-Mixed	12	27	32	14	29
	Picture/Digit naming				
Blocked context	564 (17)	536 (15)	568 (17)	528 (17)	421 (16)
Mixed context	537 (14)	507 (14)	531 (16)	514 (15)	467 (16)
Blocked-Mixed	27	29	37	14	-46

Summarizing, the results of Experiment 2 showed that the manipulation of the semantic context produced a different effect on the numerical category as a function of the notation in which they were presented. When participants responded to symbolic notation (i.e., digits) we found that the semantic blocked context produced facilitation relative to the mixed context. However, when participants responded to physical numerosity (i.e., dice) the blocked context produced longer response latencies. Therefore, with physical numerosity, which is assumed to

require a conceptual mediation in order to be named, we found an interference effect similar to the effect found in picture naming. Since models of numerical cognition (e.g., Dehaene, 1992; McCloskey, 1992) assume that the magnitude representation is common for symbolic and non-symbolic numbers, the present results indicate that the facilitative effect found with Arabic digit and number word in our previous experiments (Experiment 1; Herrera & Macizo, in press) is not a peculiarity of the numerical category, but that it depends on the format since interference is found for physical numerosities. This pattern of results suggests that semantic processing is not needed when participants name symbolic numerals while it is required to produce non-symbolic numerals.

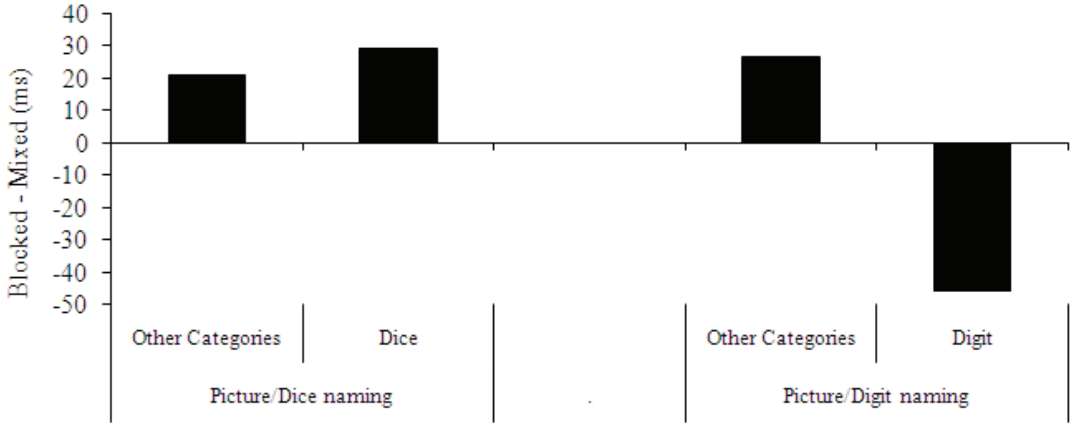

Figure 2. Effect of blocked context (Blocked – Mixed condition) for the different conditions used in Experiment 2.

3. General Discussion

The present study aimed to investigate whether the accessing to phonological codes required to naming numerical items differed as a function of the notation in which numbers are presented. As we exposed in Introduction section, there is general consensus (e.g., Damian, 2004; Dehaene, 1992; McCloskey, 1992; Reynvoet et al., 2002; Roelofs, 2006) about the processing route for number word naming which, similar to other words, involves the direct access to the lexical level (i.e., lemma and word-form) without semantic mediation. Also, there is consensus about an obligatory semantic stage when physical numerosity (e.g., sets of dots) has to be named (e.g., Dehaene, 1992; McCloskey, 1992; Roelofs, 2006). However, the arguments on the processing stages in the case of Arabic digits have taken two different positions: The semantic route hypothesis (e.g., Brysbaert, 1995; Damian, 2004; Fias et al., 2001; McCloskey, 1992) and the non-semantic route hypothesis (e.g., Cipolotti & Butterworth, 1995; Dehaene, 1992; Roelofs, 2006).

In order to explore this issue, we proposed to use the semantic blocking paradigm (Kroll & Curley, 1988). This research strategy has been extensively used in psycholinguistic studies to explore whether the naming of stimuli requires semantic mediation (e.g., Damian et al., 2001; Kroll & Curley, 1988; Kroll & Stewart, 1994). In this paradigm, participants have to name stimuli in the context of the same category members or in the context of mixed categories. The usual pattern of results consists of longer naming latencies in blocked context relative to mixed context when stimuli are pictures, while no differences or a facilitation effect is found with words (e.g., Damian et al., 2001; Kroll & Stewart, 1994). This differential effect of semantic context between word and picture naming is generally interpreted as a consequence of the different processing stages required for accessing to the word-form from words and pictures.

In a previous study (Herrera & Macizo, in press) we adapted this paradigm to the numerical category. Arabic digits were mixed with pictures and number words were mixed with name of objects from other categories. We reported that for both Arabic digits and number words a facilitation effect was produced by the blocked context relative to the mixed context, which would indicate that these two types of symbolic number notation might be named without semantic mediation.

The results of the present study further clarified this question. In Experiment 1 we found similar results to our previous study (Herrera & Macizo, in press) even when Arabic digits were mixed with words and number words were mixed with pictures. This result indicated that the facilitation produced by the blocked context on the numerical stimuli does not depend on the modality in which other categories are presented during the naming task.

Therefore, it excluded possible explanations in terms of response criterion adopted by the participants as function of the different difficulty of the stimuli in the task (e.g., Lupker et al., 1997; Meyer et al., 2003; Taylor & Lupker, 2001). In Experiment 2 we compared the semantic blocking effect between symbolic (Arabic digit) and non-symbolic (dice) numerosity. The results showed that the blocked context produced interference for dice faces but facilitation for Arabic digits. The interference observed for physical numerosity is in accord to models of number processing (e.g., Dehaene, 1992; McCloskey, 1992) since it is assumed that in order to name physical numerosity there should be a previous step of accessing to the magnitude representation. Moreover, the oposite effect between symbolic and non-symbolic numerical notation indicated that the facilitation observed with numerical symbols (Arabic digit and word) is not a caracteristic of the numerical category, since the magnitude representation seems to be common for symbolic and non-symbolic numerals (e.g., Herrera & Macizo, 2008; Piazza, Pinel, Le Bihan, & Dehaene, 2007; Roggeman, Verguts, & Fias, 2007; Temple & Posner, 1998).

As we exposed in Introduction section the bulk of research about semantic vs. non-semantic route in digit naming have taken the priming paradigm as research strategy. An argument used as evidence of the semantic mediation has been the finding of semantic priming effect produced by the numerical distance between numbers (e.g., Brysbaert, 1995; Ischebeck, 2003; Reynvoet et al., 2002). The closer the semantic distance between prime and target, the faster the respose to the target. However, although this pattern is similar to the one found in word naming (e.g., Chiarello, Burgessm, Richards, & Pollack, 1990; Lupker, 1984; Moss & Marslen-Wilson, 1993; Neely, 1990; Tanenhaus & Lucas, 1987) it differs from the effect found in picture naming studies. For example, Vigliocco, Vinson, Damian, and Levelt (2002) found that the closer the semantic distance among pictures to be named, the larger the naming latencies. The blocked condition of Experiment 2 allows us to explore whether this opposite effect of the semantic distance occurs for Arabic digits and physical numerosity. In order to examine this possibility, we grouped the responses in the blocked conditions as a function of the distance from the previous item in small distance (distance equal to 1, 2 and 3) and large distance (distance equal to 4, 5, 6, 7 and 8). We conducted a 2 (type of notation) x 2 (distance) ANOVA, which indicated a significant effect of the type of notation, $F(1, 34) = 45.43$, $MSE = 9650$, $p < .001$. The distance effect was not reliable ($F < 1$). The Type of notation x Distance interaction was significant, $F(1, 34) = 7.72$, $MSE = 889$, $p < .01$. The distance effect was marginal for the digit notation, $F(1, 34) = 3.61$, $p = .06$, and it also was marginal for the dice notation, $F(1, 34) = 4.12$, $p = .05$. However, the effect was in opposite direction for each notation. For dice faces, small distance produced larger response latencies (583 ms) than large distance (564 ms). For Arabic digits, small distance produced shorter response latencies (407 ms) than large distance (427 ms). The different effect of semantic proximity between numbers depending of their notations seems to suggest again, that semantic mediation is required only for the naming of physical numerosity but not for the naming of numerical symbols. Arabic numbers semantically closer (small distance) are named more slowly resembling the effect obtained for pictures of objects semantically closer in the same category (e.g., Vigliocco et al., 2002).

Summarizing, the results of the present study clearly indicate that the processing stages required to name numerical stimuli depend on the notation in which they are presented. Numerical symbols (Arabic digits and number words) can be produced bypassing semantic while the production of non-symbolic numerals (dice faces) required a conceptual mediation.

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